A WETNET STUDY OF WINDS, STORMS AND AIR-SEA FLUX MODELING

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INTRODUCTION

The inclosed body of work has been produced in whole or part during the contract study: A WETNET Study of Winds, Storms and Air-Sea Flux Modeling, NAGW-1770, administered by Dr. James Dodge of the WETNET program. This study has included significant scatterometer results (from SEASAT) since one of our goals is to achieve maximum interaction between the SSM/I and scatterometer data. A large amount of work has gone into developing the software ability to smoothly integrate WETNET SSM/I products with outside data such as that of the ERS-1 scatterometer. These products are currently available on the University of Washington internet system. The PBL programs discussed in the papers are available in UNIX or PC/DOS formats.

This is a study aimed at the use of satellite geophysical data in conjunction with a PBL model to develop our understanding of the marine boundary layer, air-sea interaction, and storms dynamics. The primary approach is to incorporate asynoptic satellite data into synoptic-scale storm domains. We then compare model output of winds, fluxes and surface pressure fields with observations and NMC or ECMWF analyses. This comparison has evolved into a verification procedure for satellite determined marine winds, and the PBL model accuracy. The agreement which we present can be seen as successful verification of both.

The UW PBL model is the basic tool for our calculations. It has seen wide use at several institutions in mesoscale to synoptic weather and climate analyses. This two-layer simi-

larity model is used to calculate PBL point wind profiles, air-surface fluxes and also can be used to translate surface wind vector fields into surface pressure data. The model's efficiency in approximating the large-eddies and the subgrid processes which are most important for flux calculations in the PBL makes it suitable for use in general circulation modeling (Foster and Brown, 1991). The windfields and surface pressure fields, together with SSMI data on integrated water vapor and moisture, give an excellent picture of synoptic scale storms.

This study used WETNET processes, McIdas software, Sun/UNIX-PC/OS2 interaction, and ancillary data merging to relate satellite data and geophysical parameters. This information will be suitable for large-scale experiment applications (WOCE, TOGA, GEWEX) and as initialization for GCM modeling. The goal was to develop a module which translates satellite asynoptic swath data into models which produce global energy budgets. The air-sea fluxes will be determined from state-of-the-art PBL models and flux parameterizations. Products which will be valuable for other investigations include surface stress fields for ocean current models, surface pressure fields for comparisons with NMC-type fields and satellite wind validations, windfields for bulk flux calculations and coordination with cloud processes, and comparisons between the satellite derived flux models and experimental data. We plan to transfer the basic models to the WETNET system. The contributions of this study are exactly those wanted for the Global Climate Modeling and Data Assimilation program.

We have developed programs to assimilate satellite asynoptic data (specifically, ERS-1 and SSM/I) onto lat/long grids, interpolate and extrapolate these swath data to gridpoints, and overlay NMC format data onto this grid. These data can be used to establish wind directions for SSM/I windspeeds or for determining the effects of stratification and/or thermal winds. These data constitute boundary conditions for the PBL model, which then produces a coordinated windfield, surface pressure field, stress and heat flux fields, and vertical wind profiles.

Scatterometer related WETNET work concentrated on two distinct scales: the large (general circulation) scale (Levy & Tiu, 1990, Levy, 1992), and the synoptic storm scale (Levy & Brown, 1991). Our large scale work has focussed on the role that thermal advection plays (statistically) in preferential low level meridional mass transport, and the detection of this effect in scatterometer data. In addition, we have examined and documented the large scale low level circulation statistics of the southern hemisphere as diagnosed from both scatterometer and conventional analyses.

Our work with the WETNET SSM/I data concentrated on evaluating the windspeed algorithms and the various liquid water effects. David Bright's thesis "Evaluation of SSM/I Sea Surface Wind Speeds for Meteorological Purposes", established specific limits (0.25 - 0.5kg/m^2) beyond which wind speeds are invalid. The algorithm of F. Wentz (1991) contains physical arguments based on water vapor effects. It is still being compared to the statistically based procedures for relating windspeeds to brightness temperatures.

Suzanne Dickinson has catalogued Northern Hemisphere storms for the 1987 SSM/I WETNET data. The storms analysis (frontal location and genesis, low center, maximum wind speeds and water contents) derived from SSM/I algorithms has been compared to NMC analyses. An algorithm to produce neutral stratification u* and z_o from SSM/I windspeeds has been incorporated into the WETNET software. Other work includes cataloguing Southern Hemisphere storms and comparing to Australian Bureau of Meteorology (ABM) analyses. She has been active in the development and debugging of WETNET commands and capabilities in work with V. LaFontaine and M. Smith.

Our storm scale WETNET work has involved developing a practical application of SEASAT scatterometer data for determining synoptic storms pictures in the southern hemisphere. We have documented success with this process in the northern hemisphere (Brown & Levy, 1986). However, our initial comparisons in a belt between 30-60S (Levy, 1989b; Levy & Brown, 1991) revealed wide discrepancies between our pressure fields and those of the ABM, and those of the European Center for Medium-range Weather Forecasts (ECMWF). Although there is fair agreement near continental weather stations at the southern tips of Australia, Africa and South America, there are important disparities farther south. Considering the agreement in the good surface data coverage regions of the northern hemisphere, our contention is that the weather service and numerical models are wrong (however, they have updated their procedures since 1978).

In related studies, we are examining the ability of GCM models of the PBL to represent the fluxes. There are two weaknesses in this vital link to successful weather and climate analysis: 1) the flux parameterizations are sometimes inaccurate (e.g. land measurements extrapolated to ocean values); and 2) the parameterization is inevitably done with respect to U_{10}, a value which may be only approximated in GCMs. During the next several years, progress can be expected on both of these problems (from GEWEX experiments and in large-eddy modelling). The WETNET system with our PBL models is ready to absorb the results from these studies.

Our dynamics studies will closely interact with other investigations of moisture and water states. The inverse PBL model will also be used to routinely relate NMC (or ECMWF) data to the satellite winds. The vertical integration of surface winds using the direct PBL model is necessary for good GCM data utilization. The ability to produce surface pressure fields from satellite surface wind fields provides a valuable connection between satellite data and synoptic observations.

THESIS

The SSM/I data was closely examined by David Bright in his thesis work (not included in this volume),

> Evaluation of Special Sensor Microwave/Imager Sea Surface Wind Speeds for Meteorological Purposes, MS Thesis by David R. Bright, University of Washington Dept. Atmospheric Sciences, 166pp, 1990.

This thesis examined SSM/I data in three environments with several case studies in each. The first involved Buoy and SSM/I comparisons; the second was an analysis of Hurricane Gilbert with ship, buoy, aircraft, and NMC/PBL model data compared to SSM/I data; and the third involved Pacific frontal observations. These studies established the basic criteria for our model analyses of SSM/I data. These include wind speed accuracy within 2 m/s provided cloud water cutoff is at RC = 0.50 kg/m^2; a regional bias of 1.2 m/s for Pacific ocean data; SSM/I winds provide more accuracy than NMC plus PBL model on grid scales of less than 100km; and SSM/I data can yield information near fronts and Pacific lows provided the RC limit is observed.

PUBLISHED PAPERS

The publications supported wholly or in part by this grant are:

Brown, R.A.; Surface Fluxes in Air-Sea Interaction and Remote Sensing, Chapter 2 in *Surface Waves and Fluxes: Current Theory*, G.L. Geernaert and W.J. Plant, Eds. Reidel, Dordrecht, 372pp, 1990.

----; The Scatterometer: Data and Applications, Chapter 4 in *Microwave Remote Sensing for Oceanographic and Marine Weather-Forecast Models*, Ed. R.A. Vaughan, 99-123, Kluwer Academic Pub., 406pp, 1990.

_____; Meteorology, Chapter 1 in *Polar Oceanography*, W.O. Smith, Ed., Academic Press, 406pp, 1990.

-----; Weather from Space, reprinted from *Proceedings of Oceans '90*, Washington, D.C. Sept. 24-26, 1990.

Katsaros, K. & R.A. Brown; Legacy of the Seasat Mission for Studies of the Atmosphere and Air-Sea-Ice Interactions, *Bulletin AMS*, **72**, 7, 967-981 1991.

Levy, G., 1989: Surface dynamics of observed maritime fronts. *J. Atmos. Sci.*, 46, 1219-1232.

----, and R.A. Brown; Southern Hemisphere synoptic weather from a satellite scatterometer. *Monthly Weather Review*, **119**, 2803-2813, 1991.

——, and F.S. Tiu, 1990: Thermal advection and stratification effects on surface winds and the low level meridional mass transport., *J. Geophy. Res.*, 1990, 95, pp. 20247-20257.

Submitted papers:

Etling, D. and R.A. Brown; A Review of Large-Eddy dynamics in the Planetary Boundary Layer, submitted to *Bound.-Layer Meteor.*, 1992 (solicited paper; not in this volume).

Brown, R.A. and Ralph Foster; A Two-Layer Similarity PBL Model with Coherent Structures, for *Jn. Atmos. Science*.

This work is ongoing, and we expect several more publications from this work, including S. Dickinson's thesis.

PRESENTED PAPERS

The work has also been presented in several meetings & seminars:

Brown, R.A.; PORSEC First Meeting, Okinawa, session keynote, *Energy Flux. Air-Sea Interaction*, and paper on *Scatterometer capabilities to measure surface winds*, August, 1992.

---; Colloquim given to Oregon State University Atmospheric Sciences Dept., *A Planetary Boundary Layer Model with Coherent Structures*, May 28-29, 1992

------; Covener of section and invited talk on, *Chaos, strange attractors and coherent structures in geophysical fluid dynamics*, AGU Fall meeting, San Francisco, CA, December 9-13, 1991.

----; IGARSS-91, Espoo, Finland, 3-7 June, 1991; *Relating the Microwave Radar Cross Section to the Sea Surface Stress: Physics and Algorithms*, (with D. Weissman, W. Plant, K. Davidson & W. Shaw).

----; Fraunhofer Institut fur Atmospharisch Umweltforschung, Garmisch/Partenkirchen, Germany, invited seminar: *The Importance of Instabilities and Coherent Structures in Pollution Modeling of the PBL*, May 31, 1991.

---; European Geophysical Society, XVI General Assembly, Wiesbaden, 22-26 April 1991, paper presented, *Forecasting the Weather with Satellite Microwave Data*

---; Oceans 90, Plenary session keynote talk on *Weather from Space*, Washington DC, (Sep. 1990)

---; Satellite Meteorology and Oceanography, a conference presented by RMS, AMS and WMO at the Royal Soc., London, 3-7 Sept. 1990. *Southern Hemisphere synoptic pressure fields from a scatterometer.*

---; CNES, French Met. Institute, *The scatterometers*, Paris, France (August, 1990)

---; University of Munich, *Scatterometry*, Munchen, Germany (August, 1990)

---; 9th Symposium on Turbulence & Diffusion, *Modeling the Effects of Organized Large-Eddies in K-Theory*, Riskolde, Denmark (1990)

--- and David Bright; Oceans-91, Hono. HI, Oct 1-3 1991, *An Evaluation of Special Sensor Microwave/Imager Sea Surface Wind Speeds*, & Chair of session on Remote Sensing of Surface Winds and Waves.

---- and Ralph Foster, 1991; AGU Fall meeting, Dec. 1991, *Coherent Structures in the planetary boundary layer.*

---, and G. Levy; IGARSS-91, Espoo, Finland, 3-7 June 1991, *Southern Hemisphere Surface Pressure Fields from Space.*

Foster, Ralph and R.A. Brown; AGU Fall meeting, Dec. 1991, *A comparison of GCM PBL results with the UW PBL model fluxes and 10 meter winds.*

Levy, Gad, 1992: Hemisphere Low Level Wind Circulation Statistics From The SeaSat Scatterometer. (presented IUGG, Vienna August 1991).

----; IV Latin American Symposium on Remote Sensing, Bariloche, Argentina, 1989. *Southern Ocean storms as viewed by satellite scatterometer and microwave radiometer*, Preprint volume.

----; 3rd International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, 1989. *Meteorological applications of remote sensors over the Southern Ocean.* Preprint volume.

—— & R.A. Brown, 1992: On Satellite Data Assimilation into PBL Models., Preprints, *Sixth Conference on Satellite Met. and Ocean.*, Jan 5-10, 1992, 142-144.